Methodologies and Early Results in the Application of the Energy Analysis Program to the Italian Context

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by Dario Padovan[1], *Fiorenzo Martini*[2] *and Alessandro K. Cerutti*[2]

1. Introduction

This article outlines the methodological guidelines that will be applied in the framework of the GERME program in order to assess the sustainability of consumption patterns in Italy on the base of the household metabolism concept. A hybrid Input-Output and Life Cycle Assessment method from Wilting (1999) and further studies (Kok et al. 2003; Benders et al. 2006) is investigated for application in the Italian context. This method quantifies the total energy demand of households as a proxy for environmental pressure related to household consumption for a given population (which can be a city, a region or a country, according to the survey). Analyses of different types of households are useful in order to identify specific energy patterns related to specific expenditure patterns. The idea that stands at the base of this analytical protocol is that a thermodynamic assessment of different types of households provides useful information about options for change in lifestyle.

The evaluation of the sustainability of the way societies produce and consume is becoming a central issue for both environmental and social sciences. Several consumption patterns (or more generally lifestyles) are claimed to be sustainable, but evaluation of different social scenarios from a environmental point of view is quite difficult to achieve and suitable tools are required.

At the World Summit for Sustainable Development in Johannesburg, world leaders recognized that it is necessary to promote sustainable patterns of production and consumption and to increase the ecoefficiency of products and services (WSSD 2002). According to the Johannesburg Implementation Plan this major challenge should be met through the adoption of tools, policies, and assessment mechanisms based on life-cycle analysis. It is remarkable that the United Nations General Assembly cites Life Cycle Assessment (LCA) as the most suitable tool for this challenge; nevertheless theoretical problems may arise in the application of a product-oriented LCA to a society, and many hybrid methodologies are proposed (e.g., Wiedmann 2009; Hertwich 2011). A number of hybrid LCA methods were used as assessment tools for comparison of family consumption in certain European countries (e.g.,, Kok et al. 2003), but no complete applications have been conducted yet in Italy.

This research context was adopted by the research framework of the Green Economy Scenarios in the Mediterranean Region (GERME) program established by the Regio Collegio Carlo Alberto. The main focus of the first part of the GERME project is the relationship between socio-economic dynamics (supply and demand levels and composition, water and energy consumption, pollutant emissions, demographic trends, environmental policies) and environmental dynamics (pollution, CO_2 concentration and climate change),

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with a specific focus on feedbacks existing between the two dimensions. Thus the main objectives of this part are: (I) to highlight the most sustainable consumption patterns for Italian families and (II) to investigate sociological aspects of the resulting consumption scenario. This contribution has been prepared in order to illustrate problems and potentials of the application of such methodology in the Italian context.

2. From the Energy Use of Production to the Sustainability of Consumption Patterns

2.1 Energy in Consumption Practices

Several international surveys (e.g., Tukker et al. 2006) underscore that commonly prescribed measures to reduce family energy consumption, such as running dishwashers and washing machines only when they are fully loaded, taking showers instead of baths, lowering indoor temperatures at night, turning off lights when leaving a room and others, are almost of no effect in lowering energy consumption. Some authors (e.g., Kok et al. 2003) point out that the limitation of such recommendations is that they focus on just part of a household's energy consumption and not the household total. The other part of total energy is indirect energy, which includes the energy needed to produce the goods and services used in industries, in the transport sector, and in retail as a result of consumer demand (Benders et al. 2006). This part of energy consumption can be relevant; e.g., Vringer and Blok (1995) found that 54% of the total average energy demand for a Dutch household was indirect.

So indirect energy has to be considered in order to properly quantify the energy consumption of a lifestyle and, hence, its full energy-saving potential. Research has already shown that some consumption behavior may lead to a reduction in total energy consumption, such as a dietary change toward less meat and more seasonal vegetables (Carlsson-Kanyama et al. 2003), reuse of products and a shift in leisure activities away from holidays abroad (Lenzen and Dey 2002). Despite these examples of changes in specific consumption behavior, major assessments of full consumption patterns are difficult to achieve. So, many studies relate environmental assessment to household consumption (Spangenberg and Lorek 2002).

2.2 Household Metabolism

The conceptual base of applying environmental assessment methods at the family level can be found in the household metabolism concept. According to this concept the family level is the one that enables evaluation of the environmental impact of a community/country due to the strong bonds between household consumption and the processes of producing and managing goods (Fig. 1.).

Household metabolism is part of the family of methods that use a "metabolic perspective" to analyze the interactions between society and nature. A metabolic perspective allows us to understand where the interface between nature and society has problems, strengths or limits. Furthermore it allow us to evaluate where there is a decrease in resources because, at some point, a given social system is starting to show disturbances and crises altering the process of material exchange and jeopardizing its survival. The metabolic analogy can work not only for proto-capitalist societies, which have a relatively simple metabolic profile, but especially for advanced societies, because metabolism is historically determined, depending on the variety of systems that organize and regulate the exchange between society and nature (Fischer-Kowalski and Haberl 1998). Unlike other methods based on the same metabolic pattern, such as Material Flow Analysis, the household metabolism model does not base its evaluation on the national system and its environmental accounts on a top-down-to-micro approach; rather, it starts from the household and follows a bottom-up approach.

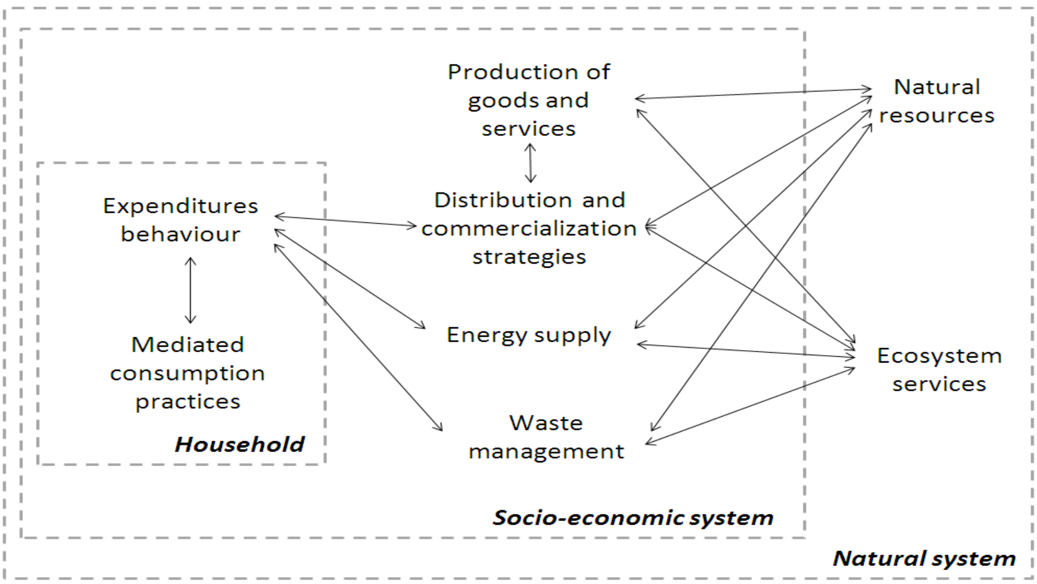

Fig. 1. Schematic representation of the household metabolism model. Family consumption is strongly connected with the production of goods and services, energy supply, and waste management. These processes are themselves related to the consumption of natural capital in term of resource used and pollutant emitted.

The socio-economic metabolism measured by the household's final consumption includes all energy that is consumed directly and indirectly in the processes of production of final goods, which enables direct accounting of biotic consumption, consumption of consumer production and consumption of the whole system.

At the same time, household metabolism makes it possible to identify different types of aggregation and categorization of consumption (Benders et al. 2006), providing a model to understand the stratification of consumption. This stratification model is based both on family size and on certain qualitative characteristics (income, education level, profession) that are considered to be the main structural variables in sociological research. In addition, the metabolic model for family units also allows one to identify the structure of the everyday practices of consumption by which the physiology of the socio-economic system itself can be reconstructed (Röpke 2009). The advantage of the household metabolism method is that it enables the creation of scenarios of transition toward sustainability, starting from the daily practices of families and working back to the overall system by verifying the plausibility and effectiveness of transition practices. Here acknowledgment must be accorded to the key role played in the modern market economy by consumers who, by expressing their preferences, can modify the actions of manufacturers. From an environmental perspective, the classic distinction between production and consumption loses its legitimacy and theoretical credibility, rebounding to the analytical side. From the thermodynamic point of view, this model includes both the demand for resources (flows of direct input of family resources) and indirect demand for resources (the resource flows that occur elsewhere to produce household consumption; e.g.,, in mining, in production of materials, in housing construction and in waste treatment).

2.3 Environmental Assessment of Household Consumption

Many studies address the environmental impacts of household consumption because of the overall importance of this final demand category (Hertwich 2011). In these studies various methods of modeling imports, transport and trade margins, expenditures abroad (e.g., vacations) are presented and several ways to aggregate the results in categories are proposed. These studies consider both an aggregate index, such as life-cycle assessment methods (Nijdam et al. 2005; Huppes et al. 2006) or ecological footprint methods (Wiedmann et al. 2007); and a single parameter as an indicator. In the latter case energy consumption and greenhouse gasses (GHG) are the most widely used parameters.

According to a recent literature review (Hertwich 2011) on the environmental impacts of consumption, shelter accounts for 35–53% of total energy use; mobility, including fuel use, vehicle purchase and public transport, accounts for 15–31%; food accounts for 11–19%; recreation accounts for 4–10%… clothing, 3–5%… and health, 1–5%. It should be noted that in this review the energy use in some foods, consumed in restaurants, hotels, as part of package tours, or in educational and health-care institutions, is not allocated to the food category but is listed under other, recreation, transport, or government consumption.

Taking into account the GHG emission form household consumption, comprehensive research across the Europe 25 was conducted in 2006 (Tukker et al. 2006). In this study GHG emission breaks down as 31% for food, beverages, tobacco and drugs; 2% for clothing and footwear; 24% for housing, furniture, equipment and utility use; 2% for health; 19% for transport; 2% for communication; 6% for education; 9% for restaurants and hotels; 5% other goods and services.

Although different types of resources are relevant to the analysis in the household metabolism model (which was selected for application in the GERME project), energy was chosen as the key parameter for measuring the environmental load of consumption. This assumption was made also because energy is linked to important environmental issues; furthermore energy consumption is also reported accurately within companies because of its economic importance. Whereas the use of other resources such as land and water is essentially assessed in a few specific areas, energy use occurs in every sector of the economy and society. The result is that energy is a useful indicator of the economy at the macro level as well as at the micro level of specific goods and services to be consumed by households (e.g., Kok et al. 2003, Benders et al. 2006).

Energy is therefore the key parameter of the model adopted. Evaluating the (direct and indirect) energy use of household goods and services is linked to specific environmental impacts in terms of pollutant emissions and resource consumption.

For the purposes of quantification of household consumption, the model predicts a schematization in activities of household consumption (e.g., food, holidays, private transportation) and quantification of energy consumption per unit associated with each category of activity. For example, Fig. 2 shows the results of this model applied to some Northern European countries in the project ToolSust (Kok et al. 2003).

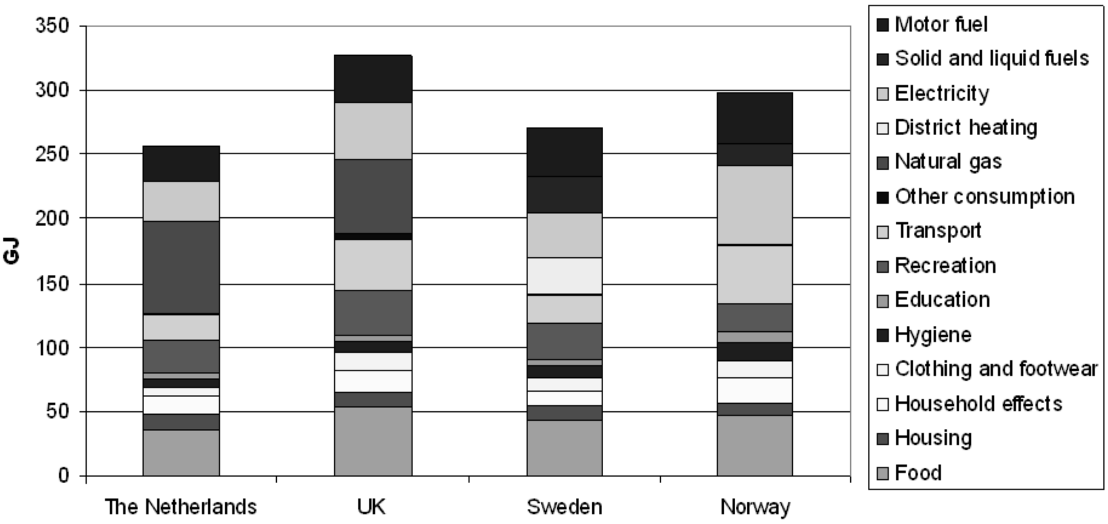

Fig. 2. Total energy consumption (direct and indirect) in the selected family consumption categories considered in the ToolSust project (Source: Kok et al. 2003).

3. The Need of a Hybrid Method

3.1. Process-Based Assessment and Macro-Economics

Because for household consumption the greatest environmental impacts take place in complex supply chains of goods and services rather than directly in fuel and/or energy consumption (Tukker et al. 2006), an assessment derived from fuel and electricity consumption alone is inadequate.

In order to assess GHG emissions and energy consumption, most companies use "bottom-up" approaches, summing estimates of emissions associated with specific goods and resources used during the productive process, thorough a process-based LCA to estimate the impacts across an inventory of activities and purchases. Nevertheless, a number of authors (e.g., Wilting 1996; Kok et al. 2003) point out that this approach suffers from "truncation error," and when applied to household consumption, leads to serious underestimation of the total impacts. The truncation arises from the inevitable omission of steps and processes in order to make the task manageable. An LCA defines the system it is describing as a finite number of steps, and in most cases these provide an adequate estimate (Baumann and Tillman 2004); but with this method it will never be possible to consider a "total economy scenario."

On the other hand are "top-down" analyses, which use Input–Output Analysis (IOA) and are able to locate emissions in different sectors considering the total economy of a country. This approach has the benefit of not underestimating global figures, but the calculations are made for economic sectors only, and not for certain products. This means that an IOA gives cruder estimates than an LCA does; on the other hand, the accounting is more comprehensive. Furthermore, IOA indicates an emission factor per Euro consumed in a certain sector. This is considered very useful, even if it could lead to "aggregation error," as the input–output coefficients for each industry are averages derived from the comprehensive natural summation of all the related, but not identical, production processes. Because individual processes are not individually discernable, however, it lacks the potential for specificity of the bottom-up approach. (e.g., Wiedmann 2009)

Therefore numerous hybrid models that combine the LCA and IOA have been developed to describe consumption systems from a thermodynamic point of view, in an attempt to benefit both from the completeness of IOA and from LCA's potential for specificity (Hertwich 2011).

3.2 The EAP Hybrid Method

The Energy Analysis Program is a hybrid (LCA-IOA) tool that has been developed at IVEM (University of Groningen), to calculate the energy requirement of households by following the household metabolism approach. This tool quantifies the total energy demand of households as a proxy for environmental pressure related to household consumption for a given population (which can be a city, a region or a country, according to the survey). The main advantages of this tool are:

(I) Contribution of capital goods.

As is well known, the Leontief model, mainly used in environmental applications, considers only intersectoral transactions of the actual productive activities in a given year. Transactions relating to the safeguarding and enhancement of fixed equipment (or stocks of raw and semifinished materials) are combined into a single item of final demand called investment. In this way, these are not endogenous to production, but are elements to be determined independently.

This effect is a problem, as the investments are needed in part to create new production capacity but also to replace equipment worn-out the share of fixed capital in the annual production process. Thus the question is: how to consider the role of investments in an analytical framework, such as the evaluation of the carbon footprint of consumption by the population? A number of methods have been proposed: there are studies that simply ignore the issue, and others that propose a complete inclusion of investments.

Nevertheless, the most appropriate method should involve the segregation, from the vector of final demand, of an amount equal to depreciation and its internalization in the matrix of cross-sectoral exchanges. This kind of solution is adopted by the EAP model, which introduces a fictitious sector called depreciation. This sector accounts for the redistribution of externalities embedded in the use of annual capital equipment based on the share of depreciation specific to each sector of the economy.

(II) Foreign Trade

Regarding the issue of foreign trade, the EAP model has the advantage of distinguishing clearly between competitive and non-competitive imports, depending on whether it is goods and services that are produced, or not, at the country level. Imports of the first type are included in the matrix of intermediate exchanges, under the assumption that the production structure of the country from which material comes is similar to that of the country examined. These assumptions are not unreasonable in the Italian context, which imports mainly from other Western countries.

4. Conclusion and Outlook

Notwithstanding the usefulness of a hybrid LCA-IOA method (and the EAP tool), a well-structured application in Italy is still missing. Within the GERME project, country-specific data from both the economic and energetic landscapes in Italy have been collected and processed to create the Italian EAP databases. Such databases have been combined with expenditure data from the National Statistical Bureau (Istat) in order to determine the total energy requirements of the average Italian household.

Early results from the adaptation of the EAP model to the Italian context show the suitability of this tool for the evaluation of energy requirements for Italian families, but precise descriptions about the production of goods and management of services considered in the survey are necessary in order to achieve significant results.

Since the beginning of 2012, the Italian EAP model has been applied to specific consumption patterns in the research framework of the Theory of Planned Behavior (Ajzen 1991). This theory proposes a model of how human action is guided. It predicts the occurrence of a specific behavior provided that the behavior is intentional.

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